Fermilab

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# BOOSTER LENGTH STORAGE RING DESIGN FOR ANTIPROTON COOLING

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In order to match an electron-cooling scheme with $\bar{p}$ production at Fermilab, it is necessary to do the cooling in a storage ring with the same circumference as the booster. In addition, one wants to be able to do the cooling on a large percentage of the circumference, approximately 15-25%. Finally, it is desirable to be able to use as much of the present proton storage ring as possible. An initial design of such a storage ring is presented below. It incorporates the present ring's curved sections and power supplies, unmodified, has a total of 100 meters of electron beam, and utilizes as few additional quadrupoles and power supplies possible, consistent with the above requirements.

The present electron cooling ring is built in a racetrack design, with two, tightly-packed curved sections connected by relatively short straight sections, one of which is to be used for the initial cooling tests.[1] It consists of 24, four-foot dipoles, and 32, two-foot quadrupoles connected to nine separate power supplies. It has a circumference of some 135 meters. In order to bring it to booster size, approximately 340 meters more need to be added. The most straightforward way to accomplish this is to cut the present ring at the end of the curved sections, and simply trombone the

the design to the desired length. This can be done by leaving the south end of the ring in its present location, moving the north end next to the linac annex, and connecting the two with very long straight sections.

The design presented cuts the present ring between the #6 dipoles and the #6 quadrupoles - i.e., B16, Q16, B26, Q26, etc, and leaves the curved sections completely unchanged. Thus the power supplies, tuning parameters, and lattice functions of the curved sections do not change at all. For simplicity, all of the electron cooling has been put into one straight section, although it may be more desirable to cool on both sides in order to achieve super-periodicity. This, however, would require considerably more quadrupoles, as well as an additional electron gun system.

The design presented bridges the straight section without the electron beam with a simple FODO channel, using four quadrupoles at each end to match into the curved lattice. The other side is somewhat more difficult due to the defocussing effect of the electron beam, as well as the required $\bar{p}$ beam size in the cooling region. The design chosen has ten cooling sections, each containing a 10 m, 13 amp electron beam, separated by a quadrupole triplet, and the complete straight section is connected to the curved lattice with a triplet at each end. Plots of the lattice for the two halves are shown in Figs. 1 and 2. Note that in Fig. 2, only two electron beams and one triplet are shown for simplicity, while, in actuality, the beam-triplet configuration is repeated nine times. This design requires a total of 36 additional 2-foot quadrupoles, and 6 additional quadrupole power supplies. Various parameters for the ring are listed below.

## Expanded Cooling Ring Parameters

| | |
|---|---|
| Number of dipoles | 24 |
| dipole effective length | 1.3125 m |
| dipole field (200 MeV) | 4.29149 kG |
| Number of quadrupoles | 68 |
| quadrupole effective length | 0.6767 m |

### Curved Section

| | | |
|---|---|---|
| Drift length (D0) | | 1.9455 m |
| Drift length (D1) | | 0.3789 |
| Drift length (0) | | 0.8340 |
| Quadrupole gradient | Q0 | 6.6759 kG/m |
| | Q1 | -13.1961 |
| | Q2 | 13.1961 |
| | Q3 | -15.8528 |
| | Q4 | 15.8528 |
| | Q5 | -17.3551 |
| Quarter arc (C) | | (D0)Q0(D1)B(0)Q1(0)B(0)Q2 (0)B(0)Q3(0)B(0)Q4(0)B(0) Q5(0)B |

### Straight section without $e^-$ beam

Matching section

| | | |
|---|---|---|
| Drift length | (DW1) | 3.000 m |
| | (DW2) | 1.0000 |
| | (DW3) | 5.0000 |
| | (DW4) | 3.0000 |

| | | |
|---|---|---|
| Quadrupole gradients | QW1 | 13.1810 kG/m |
| | QW2 | -11.5192 |
| | QW3 | 1.3739 |
| | QW4 | -2.0626 |
| Structure (TW) | (DW1)QW1(DW2)QW2(DW3)QW3(DW4)QW4 | |

FODO Section

| | | |
|---|---|---|
| Drift length (DW) | 19.7062 m | |
| Quadrupole gradients | QF | 2.2336 kG/m |
| | QD | -2.1659 |
| Structure (FODO) | QF(DW)QD(DW) | |

Half Ring Structure (W)

$(C)TW(DW)FODO(FODO)FODO(QF)DW(\overline{TW})\overline{C}$

Straight section with electron beam

Matching section

| | | |
|---|---|---|
| Drift length | (DE1) | 0.9343 m |
| | (DE2) | 1.3221 |
| | (DE3) | 0.6956 |
| Quadrupole gradients | QE1 | -11.5223 kG/m |
| | QE2 | 19.7050 |
| | QE3 | -14.9517 |
| Structure (TE) | (DE1)QE1(DE2)QE2(DE3)QE3 | |

Beam Section

| | | |
|---|---|---|
| Drift length | (DE) | 2.2784 m |
| | (D) | 1.0000 |
| Quadrupole gradients | QTF | 8.8190 kG/m |
| | QTD | -4.6017 |

| | |
|---|---|
| Electron beam (Beam) | 10.02 m |
| | 13 Amp |
| Beam Structure (EB) | (DE)Beam(DE) |
| Triplet Structure (TRP) | QTD(D)QTF(D)QTD |

Half Ring Structure (E)

(C)TE(EB)TRP(EB)TRP(EB)TRP(EB)TRP(EB)TRP(EB)
TRP(EB)TRP(EB)TRP(EB)TRP(EB)$\overline{\mathrm{TE}}$($\overline{\mathrm{C}}$)

Entire Ring (E) (W)

| | | |
|---|---|---|
| | Total length | 474.2027 m |
| Tunes:(*) | $Q_x$ | 5.47 |
| | $Q_y$ | 7.23 |

Beam parameters in cooling region

$$\beta_x = \beta_y \text{ (center)} = 30.0 \text{ m}$$

$$\beta_x = \beta_y \text{ (ends)} = 34.2 \text{ m}$$

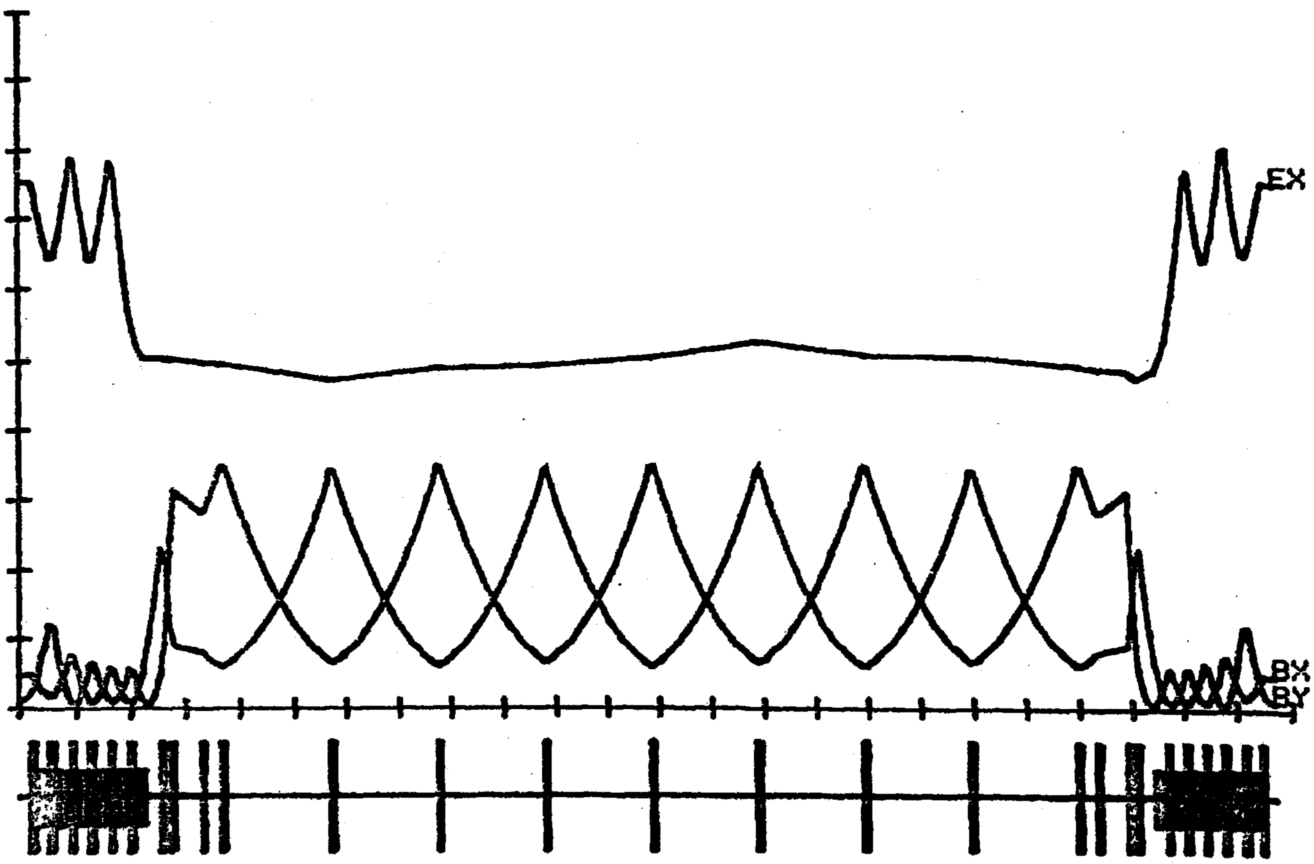
$$\eta_x \simeq 0.2 \text{ m}$$

*N.B. Tunes have not been optimized, but are easily changeable.

Reference

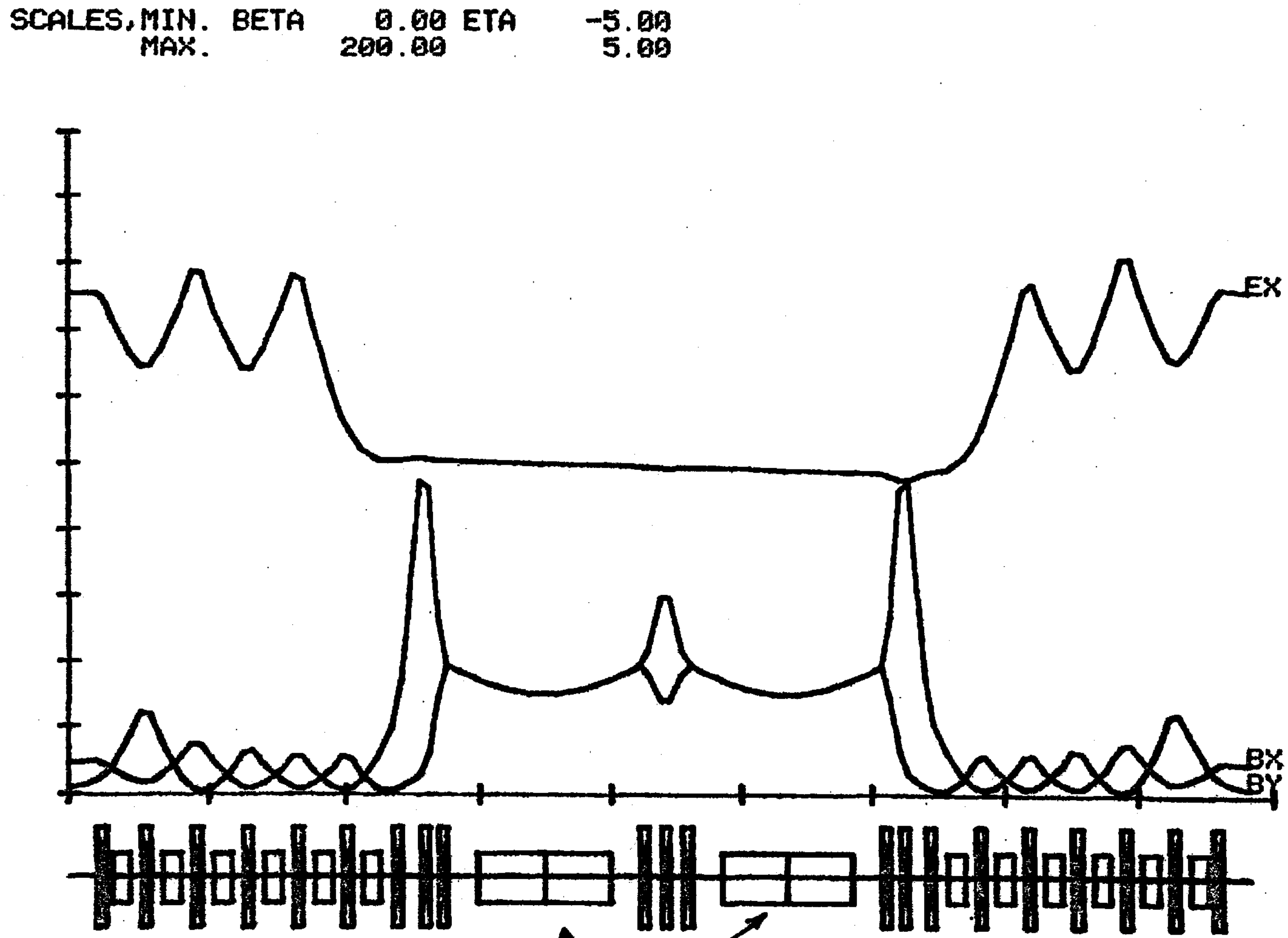
1. "Fermilab Electron Cooling Experiment Design Report", August 1978

SCALES,MIN. BETA 0.00 ETA -5.00
MAX. 200.00 5.00




*Expanded cooling ring, west half*

Figure 1




10 m, 13 A e⁻ beams each.
Total of 10 such sections w/ triplet in between each.

Expanded Cooling Ring, east half. P-bar's.

Figure 2